ESS 545

EXPECTED RETURN AND RISK - A TRADE-OFF IN FARM ENTERPRISE CHOICE

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Abstract

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A modified linear programming alternative, Hazell's MOTAD model, is used to address an enterprise choice problem in which the enterprise alternatives differ substantially in average net return and risk. Examination of several specific questions related to the trade-offs between return and risk demonstrate the model's usefulness.

Expected Return and Risk - A Trade-off in Farm Enterprise Choice

Making decisions under risk is a major problem confronting managers of any firm. Risk is now widely recognized as a key factor in most farm enterprise choice problems. The trade-off between net return and risk is at the heart of this decision problem. Agricultural economists have used a wide variety of operational techniques in their studies of the impact of risk on enterprise choice. A major hurdle has been the development of information which farmers can use directly in decision making.

In this paper, we report on a study of farm enterprise choice in which the enterprise alternatives differ substantially in average returns above variable costs and in variance of returns. The farm decision makers involved are very much aware of the return and risk differences and these differences explicitly influence their decisions. Specifically, the problem involves cash grain and specialty crop (processing tomatoes and cucumbers) farmers in Ohio. These farmers may be considering an expansion of their high risk specialty crop enterprises, a change from hand harvest of tomatoes to the more risky and capital intensive mechanical harvest of tomatoes and/or the addition of specialty crops to their conventional corn, soybean and wheat enterprise farm plans in order to increase net returns.

Given the characteristics of this problem and the importance of risk in the enterprise decisions involved, an operational procedure was needed which permitted the handling of a complex set of enterprise alternatives, explicit treatment of risk and the development of practical farm enterprise choice guidelines. We chose the modified linear programming alternative, the MOTAD model, proposed by Hazell.

Our objectives are to demonstrate the applicability of the MOTAD operational procedure to the type of problem confronted in the study, and to provide some examples of specific issues which can be addressed with the procedure.

Problem Setting

The budgeted net returns in Table 1 show the relatively high returns associated with tomatoes and cucumbers. However, a major concern of farmers who are considering adding tomatoes and cucumbers to their operations or expanding current acreage is the additional risk associated with these crops. Yields may vary substantially for specialty crops due to the interactions of complex production technology, labor management problems, and weather. Substantial yield variation results in much greater annual variation in returns for specialty crops relative to grain crops. The standard deviations of these returns calculated from 8 years of data collected from a sample of farms are shown in Table 1.

Risk influences a farmer's decisions because of the trade-offs between the higher returns and higher risk of the specialty crops and the lower returns and lower risk of the grain crops. The coefficient of variation (standard deviation of return divided by return above variable cost) quantifies these important differences in risk. The coefficient of variation is a measure of risk per dollar of expected return. Table 1 shows that the coefficients for the grain crops are significantly below those for tomatoes and cucumbers. It also can be seen that cucumbers are the most risky enterprise and that in spite of the greater standard deviation of net return for mechanically harvested tomatoes the additional net return due to reduced harvesting costs results in a smaller coefficient of variation than that for hand harvested tomatoes. These substantial differences between grain crops and specialty crops cause risk to be a major concern of the study.

Research Procedures to Deal with Risk

The use of a linear programming model is a common approach to farm planning problems. However, because risk has generally not been an explicit part of the analysis, the resulting plans show higher expected incomes and more risky combinations of enterprises than observed in practice. To include risk, Scott and Baker applied Markowitz's concept of an expected income-variance (EV) efficiency frontier to farm planning by using quadratic programming.

As an alternative to quadratic programming, Hazell developed the MOTAD (minimization of total absolute deviations) model for farm planning under risk. The model is easily solved with most linear programming algorithms having parametric options. The model minimizes the sum of the absolute values of the negative total gross margin deviations. This procedure minimizes the mean absolute deviation in net return for the total farm about the expected return for the total farm. The mean absolute deviation is a measure of dispersion of a distribution and thus it measures risk in a manner comparable to the variance used in quadratic programming. The results of the MOTAD model result in an EA frontier very similar to the EV frontier from quadratic programming (Thompson and Hazell).

To date, the MOTAD model has not been used extensively in empirical research. However, in cases where it has been used, researchers were optimistic about its capabilities and usefulness (Schluter and Mount, Kennedy and Francisco).

The MOTAD model seems appropriate for the decision problems faced by farmers in the study area who are considering specialty crops in combination with corn, soybeans, and wheat. Reasons include: (1) MOTAD's capacity for handling risk in an explicit manner, (2) major variations in mean and variance of gross margins among enterprises being considered, and (3) the need for a procedure with the capacity to accurately model the complex alternative enterprises and technologies.

Model Formulation

The basic linear programming matrix models a 600 acre representative farm with the capacity to produce corn, soybeans, wheat, mechanically harvested tomatoes, hand harvested tomatoes, and hand harvested cucumbers. There are additional activities for hiring labor, land preparation, and other support services. The constraints of the model included land, and the limiting factors of labor, machinery capacity and field time associated with critical spring planting and fall harvesting periods. It was assumed that capital was not a limiting resource.

Price and yield data for an eight year period were collected from individual farmers. Trends in these data were removed and costs were assumed to be constant over the eight year period. From these modified data, year to year deviations in gross margins were calculated for each enterprise. These data were included in the following MOTAD model formulation:

$$(1) \quad \text{Minimize} \sum_{h=1}^{s} y_h^-$$

such that

$$(2) \quad \sum_{j=1}^{n} (c_{hj} - g_j)\, x_j + y_h^- \geq 0 \qquad (\text{for } h=1,2,\ldots,s)$$

and

$$(3) \quad \sum_{j=1}^{n} f_j x_j = I \qquad (\text{for } I = 0 \text{ to unbounded})$$

$$(4) \quad \sum_{j=1}^{n} a_{ij} x_j \leq b_i \qquad (\text{for } i=1,2,\ldots,m)$$

$$(5) \quad x_j,\ y_h^- \geq 0 \qquad (\text{for all } h,\ j).$$

where

y_h^- = absolute values of the negative total gross margin deviations;

c_{hj} = the gross margin (gross revenue per acre - variable costs per acre) for the $_j$th activity on the $_h$th observation;

g_j = the average gross margin for the $_j$th activity;

x_j = the level of the $_j$th activity (usually in acres);

f_j = the expected gross margin of the $_j$th activity;

I = the expected net return;

a_{ij} = the technical requirements of the $_j$th activity in the $_i$th constraint;

b_i = the $_i$th constraint level;

s = the number of years;

n = the number of activities in the basic LP model;

and

m = the number of constraints in the basic LP model.

This model minimizes risk for each level of I (total returns above variable costs) specified in equation (3). The model minimizes risk as measured by the sum of the absolute values of the negative total gross margin deviations. Essentially this minimizes variance of returns to the farm measured by the estimator of variance

$$D\left[\frac{\pi s}{2(s-1)}\right]^{\frac{1}{2}}$$

where s is the number of years in the sample and D is the estimated mean absolute deviation in returns to the farm. In order to minimize risk while achieving a specified return level, the model selects enterprise combinations that are least risky (as measured by variance in annual returns) and/or that have negatively correlated returns. Return to the farm (I) is parameterized resulting in a minimum risk farm organization for each specified level of return. The return, risk coordinates can be graphed as in Figure 1 to show the efficiency frontier facing a farm manager with a given resource base. The decision maker can then choose a farm enterprise organization and return-risk situation which is consistent with his risk preference and goals. The rational farmer would not knowingly select a farm plan off the frontier because of an increase in risk with no compensating increase in return or a decrease in return with no compensating decrease in risk.

Results

In the first phase of the analysis, only cash grain enterprises were allowed to enter the model. The resulting efficiency frontier is illustrated in Figure 1. Net return above variable costs was varied in

$5,000 intervals. There is a specific farm plan associated with each point on the frontier. The farm plans for the cash grain frontier are shown in Table 2. This table also shows the standard deviation of net return for the farm and an approximate 95 percent confidence interval. These confidence intervals represent the expected net return plus and minus two standard deviations.

The highest return farm organization shown in Table 2 has all 600 acres of available cropland in corn. This is an unrealistic farm organization because of the risk associated with the single enterprise. The fixed costs associated with the sample farm total $87,000. This includes a $72,000 return to investment in land ($1,500/Acre x 600 x .08 = $72,000) and a $15,000 return to investment in machinery ($125,000 x .12 = $15,000). Thus, return for operator labor, management, and profit is approximately $87,000 less than the return above variable cost.

It can be readily observed from Table 2 that decreasing net returns accompany enterprise diversification. The standard deviation of return decreases and the lower bound of the confidence interval increases as return decreases. This indicates that less risk is associated with the more diversified enterprise combinations.

Farmers with return objectives not satisfied by the enterprise combinations shown in Table 2 may want to consider processing tomatoes and cucumbers. The efficiency frontier derived with an expected tomato yield of 20 tons per acre is shown in Figure 1. The corresponding farm organizations are shown in Table 3. The resource base is unchanged from that used in the grain crop analysis. It is immediately obvious that tomatoes and cucumbers extend the range of return and risk possibilities confronting the decision maker. The standard deviation of returns increase and the lower bounds of the confidence intervals decrease as returns are increased. Mechanically harvested tomatoes, hand harvested tomatoes and cucumbers, and corn become more important in the farm organizations as the returns and risk increase. Soybeans and wheat both decrease in acreage and then disappear from the solutions. Hand harvested tomatoes and cucumbers dominate over the middle portion of the frontier.

The effects of changing the expected yield for tomatoes from 20 to 24 tons per acre were also investigated. Tomato yield varies substantially among growers. It is an excellent measure of quality of management input and expertise with cultural practices because soil fertility, drainage, tomato varieties and weather are relatively homogeneous within the production area. The 24 ton per acre frontier is shown in Figure 1 and the corresponding farm plans shown in Table 4 illustrate the impact of this yield change. The increase in yield causes the frontier to shift up. With increased yields, less tomato acreage is needed to achieve a given return level. The net effect of the higher tomato yield is an increase in grain crop acreage and thus a reduction in the level of risk at any given return level.

It is important to note that the lower bound of the confidence interval increases as the net return increased to $115,000. This suggests that the increase in return up to this point more than compensates for the increase in risk. Above this level of income, however, an increase in return results in increases in risk which are large enough to cause the lower bound of the confidence interval to decrease. Thus, the trade-off between return and risk is a crucial consideration on the upper portion of the frontier.

These frontiers and accompanying tables permit a farm decision maker to evaluate the trade-offs between return and risk for his particular situation. The data allow a farmer to assess the impact of his management ability and expertise with cultural practices. Individual choice among diversification strategies is likely to be unique because of the influence of risk preference, goals, capital position and management capability.

Summary

The model allowed successful examination of the risk associated with different farm organizations and the trade-offs between returns and risk facing the decision maker. Comparisons were made between known behavior in selecting farm organizations and the results of the model. The results from the model were consistent with observed behavior in farm organization selection.

The MOTAD model allowed a successful investigation of a variety of questions which the decision maker faces. In addition, the model allowed development of decision guidelines which can be used directly by farm managers. In fact, we have found it relatively easy to communicate the results from the model to decision makers in the industry.

Although the MOTAD model was used successfully in this application, potential users should carefully assess some of its characteristics and limitations. Historical yield and price data for the enterprises under consideration must be carefully inventoried. These data are necessary for the model to capture the risk associated with the alternative enterprises. The similarity among alternative enterprises must also be carefully evaluated. When enterprises are similar in terms of expected returns and variance of returns, the risk levels are quite stable as the composition of enterprises in the farm organization changes.

Finally, the complexity of the problem being investigated should be considered. Complex problems may warrant use of the MOTAD model. However, if the problem is not relatively complex, other methods may produce equally valid conclusions.

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Table 1. Descriptive Statistics for Alternative Enterprises

Enterprise	Return Above Variable Cost Per Acre	Standard Deviation of Return	Coefficient of Variation
Corn	$172	$ 50	.29
Soybeans	122	39	.32
Wheat	90	28	.31
Mechanically harvested tomatoes	593	344	.58
Hand harvested tomatoes	335	268	.80
Cucumbers	250	272	1.09

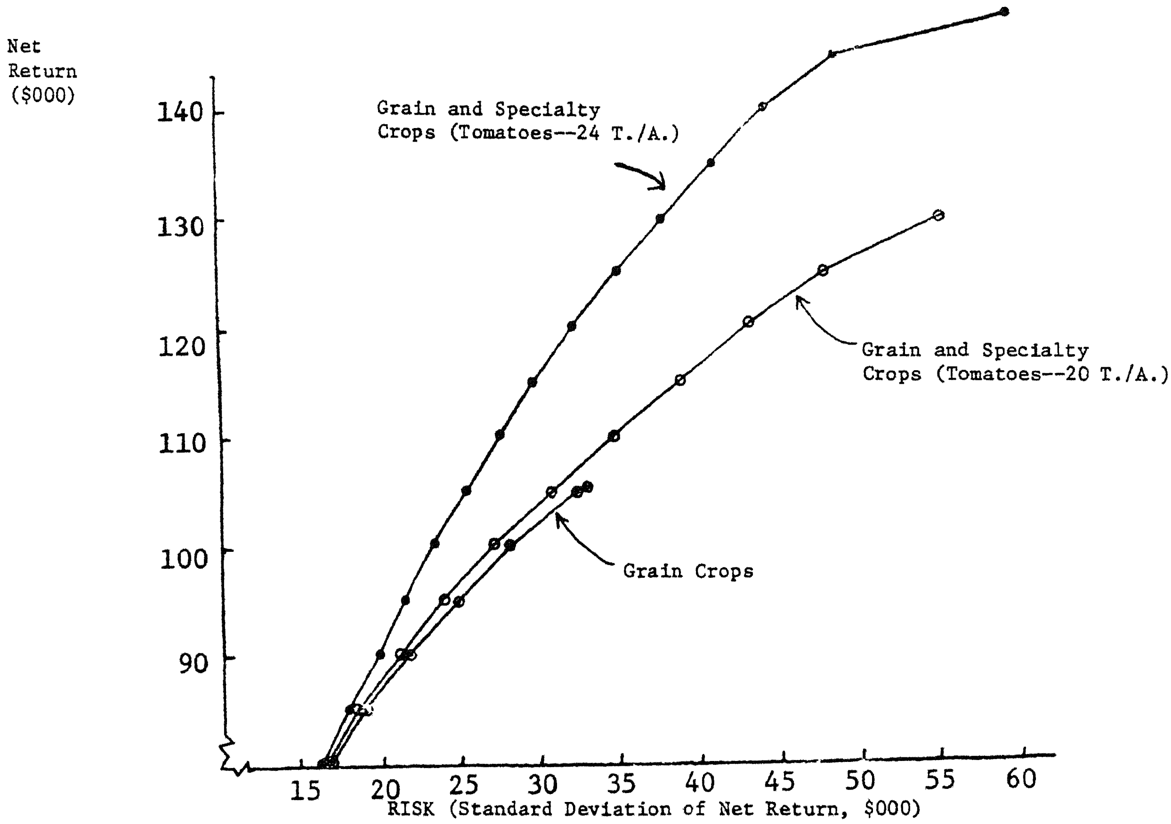

Figure 1. Efficiency Frontiers

Table 2. Farm Organizations - Grain Crops

Net Return ($000)	Corn (acres)	Soybeans (acres)	Wheat (acres)	Standard Deviation of Net Return ($000)	Confidence Interval Lower Bound ($000)	Confidence Interval Upper Bound ($000)	Coefficient of Variation
85	242	124	233	19	48	104	.22
95	383	103	114	25	46	144	.26
105	600	0	0	33	39	171	.31

Table 3. Farm Organizations - Grain and Specialty Crops (Tomatoes - 20 Tons per Acre)

Return ($000)	Corn (acres)	Soybeans (acres)	Wheat (acres)	Mechanically Harvested Tomatoes (acres)	Hand Harvested Tomatoes & Cucumbers (acres)	Standard Deviation of Net Return ($000)	Confidence Interval Lower Bound ($000)	Confidence Interval Upper Bound ($000)	Coefficient of Variation
85	221	144	230	0	5	19	48	122	.22
95	186	274	99	0	41	24	47	143	.25
105	245	302	0	15	39	31	43	167	.29
115	341	172	0	27	60	39	37	193	.34
125	437	75	0	72	16	48	29	221	.38
130	483	0	0	85	32	56	18	241	.43

Table 4. Farm Organizations - Grain and Specialty Crops (Tomatoes - 24 Tons per Acre)

Return ($000)	Corn (acres)	Soybeans (acres)	Wheat (acres)	Mechanically Harvested Tomatoes (acres)	Hand Harvested Tomatoes & Cucumbers (acres)	Standard Deviation of Net Return ($000)	Confidence Interval Lower Bound ($000)	Confidence Interval Upper Bound ($000)	Coefficient of Variation
85	130	207	136	4	24	18	49	121	.21
95	126	257	182	11	24	22	52	138	.23
105	114	332	88	5	60	25	54	156	.24
115	114	289	91	3	102	30	56	174	.26
125	114	119	235	40	92	35	55	195	.28
135	114	119	230	76	60	41	53	217	.30
145	245	87	131	86	50	49	47	243	.34
148	471	0	0	101	27	60	30	268	.40